22116115

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

CHEMISTRY
HIGHER LEVEL
PAPER 3

Candidate session number

0	0							

Tuesday 10 May 2011 (morning)

1 hour 15 minutes

Examination code

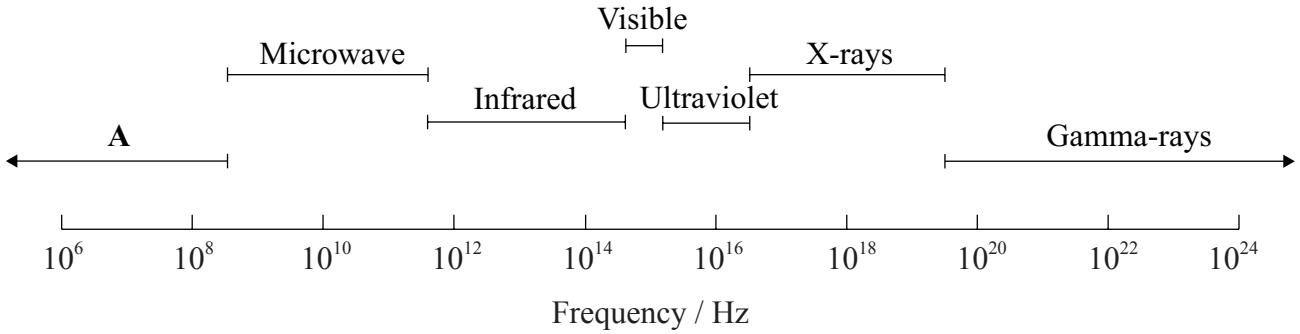
2	2	1	1	–	6	1	1	5

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options.
- Write your answers in the boxes provided.

Option A — Modern analytical chemistry

A1. Selected regions of the electromagnetic spectrum are represented in order of increasing frequency below.



(a) Identify region **A**. *[1]*

. . . . . .

(b) Identify the atomic or molecular processes associated with microwave and ultraviolet radiation. *[2]*

Microwave:

. . . . . .

Ultraviolet:

. . . . . .

(c) Explain why the absorptions in infrared (IR) spectroscopy occur at much higher frequency than those in ^{1}H NMR spectroscopy. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

A2. Infrared spectroscopy is commonly used as an analytical technique by inorganic, physical and organic chemists.

(a) Explain why hydrogen bromide is IR active whereas bromine is IR inactive. *[1]*

. . . . . .

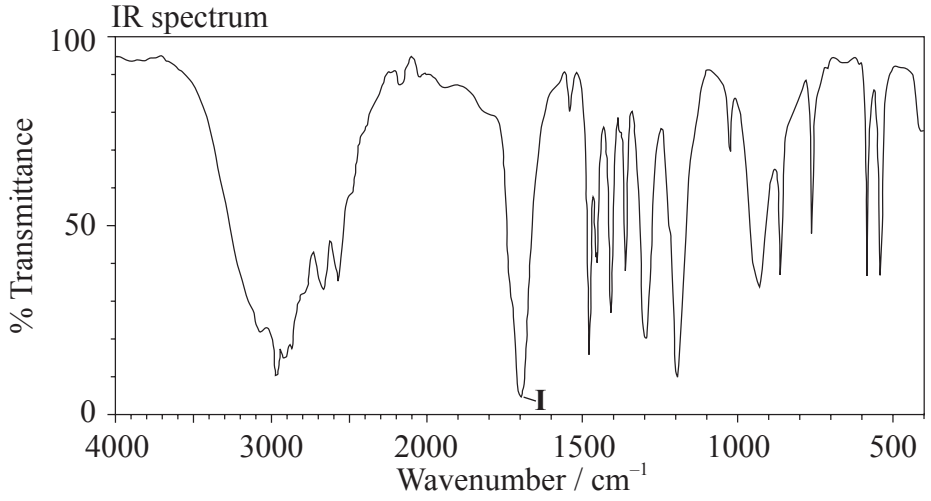
. . . . . .

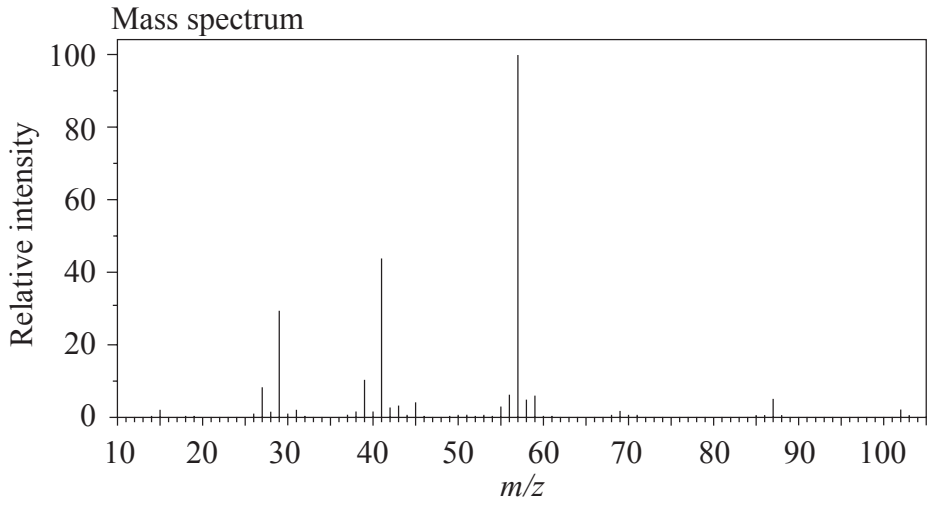
. . . . . .

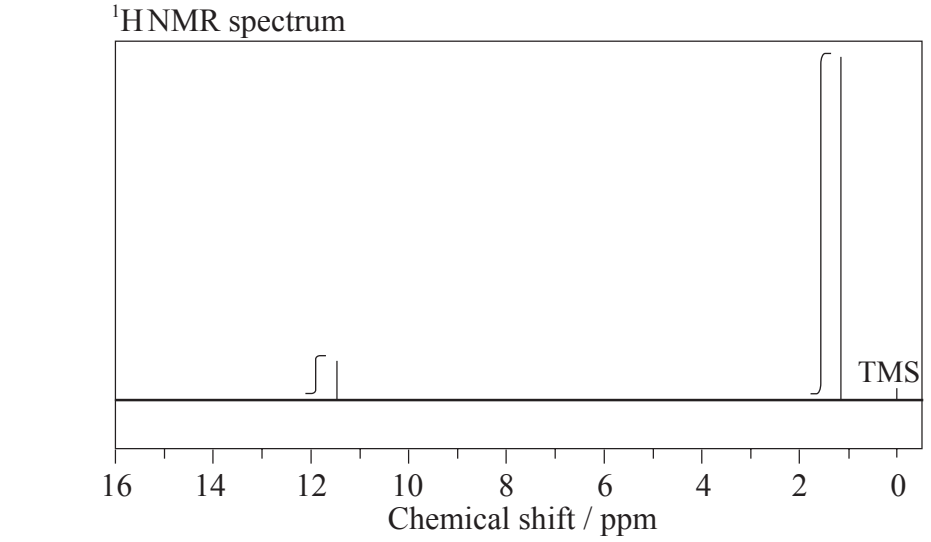
(This question continues on the following page)

(Question A2 continued)

(b) The IR spectrum, mass spectrum and ^{1}H NMR spectrum of an unknown compound, **X**, of molecular formula $C_5H_{10}O_2$, are as follows.







[Source: SDBSWeb:http://riod01.ibase.aist.go.jp/sdbs/(National Institute of Advanced Industrial Science and Technology)]

(This question continues on the following page)

(Question A2 continued)

(i) In the IR spectrum, identify the bond responsible for the absorption labelled **I**. *[1]*

. . . . . .

(ii) In the mass spectrum, deduce which fragments the *m/z* values at 102 and 57 correspond to. *[2]*

$m/z = 102$: . . . . . .

$m/z = 57$: . . . . . .

(iii) Identify the peak at 11.5 ppm in the ^{1}H NMR spectrum. *[1]*

. . . . . .

(iv) State what information can be obtained from the integration traces in the ^{1}H NMR spectrum about the hydrogen atoms responsible for the peak at 1.2 ppm. *[1]*

. . . . . .

. . . . . .

(This question continues on the following page)

(Question A2 continued)

(v) Deduce the structure of **X**. *[1]*

(vi) $HCOOC(CH_3)_3$ is an isomer of **X**. For the ^1H NMR spectrum of this isomer, deduce the total number of peaks (excluding the TMS peak at 0 ppm) and the ratio of peak areas. For **each** peak, deduce whether it is a singlet, doublet, triplet, quartet or shows a more complex splitting pattern. *[3]*

Number of peaks (excluding the TMS peak at 0 ppm):

. . . . . .

Ratio of peak areas:

. . . . . .

Splitting patterns:

. . . . . .

(This question continues on the following page)

(Question A2 continued)

(vii) $CH_3CH_2COOCH_2CH_3$ is another isomer of **X**. For the ^1H NMR spectrum of this isomer, deduce the total number of peaks (excluding the TMS peak at 0 ppm) and the ratio of peak areas. For **each** peak, deduce whether it is a singlet, doublet, triplet, quartet or shows a more complex splitting pattern. *[3]*

Number of peaks (excluding the TMS peak at 0 ppm):

. . . . . .

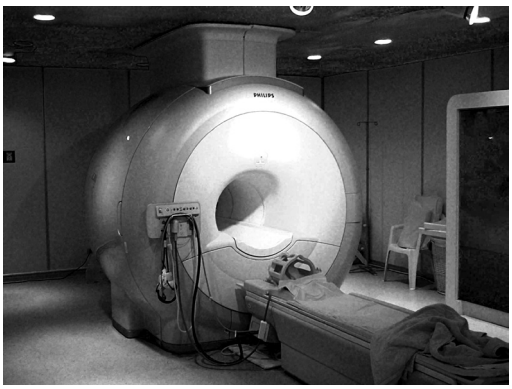
Ratio of peak areas:

. . . . . .

Splitting patterns:

. . . . . .

A3. Nuclear magnetic resonance (NMR) spectroscopy is the basis of a diagnostic medical technique called magnetic resonance imaging (MRI). The instrument used in this technique in a hospital is shown below.



[Source: http://en.wikipedia.org/wiki/File:Modern_3T_MRI.JPG]

Explain the role of NMR in this technique which can be used to obtain a three-dimensional view of organs in the human body. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

A4. Gas-liquid chromatography (GLC) is a powerful analytical technique. Outline the principles of this technique, from the injection of the sample. *[5]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Option B — Human biochemistry

B1. Triglycerides are one of three types of lipid found in the human body. The following equation represents the formation of a triglyceride.

$$\mathbf{X} + 3\text{RCOOH} \rightleftharpoons \text{triglyceride} + 3\mathbf{Y}$$

(a) Identify the compounds **X** and **Y**. *[2]*

X: . . . . . .

Y: . . . . . .

(b) Draw the structural formula of a triglyceride formed from one molecule each of octanoic acid, lauric acid and stearic acid. The formulas of the acids are shown in Table 22 of the Data Booklet. *[1]*

(c) Explain whether the triglyceride in part (b) is a solid or a liquid at room temperature. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

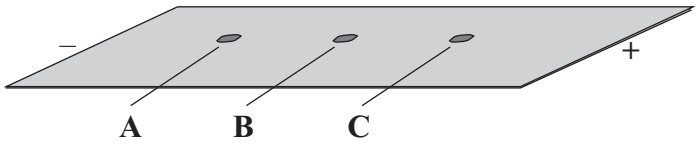
(This question continues on the following page)

(Question B1 continued)

(d) Identify the type of reaction that occurs during the formation of a triglyceride. *[1]*

. . . . . .

B2. (a) A mixture of the amino acids serine (Ser), glutamic acid (Glu) and lysine (Lys) was separated using electrophoresis and a buffer of pH 5.7. A drop containing the mixture was placed in the centre of the paper and a potential difference was applied. The amino acids were developed and the following results were obtained.



(i) Describe how the amino acid spots may have been developed. *[1]*

. . . . . .
. . . . . .

(ii) Predict which amino acid is present at spot **C**. Explain your answer. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(iii) The amino acid at spot **B** is at its isoelectric point. Describe **one** characteristic of an amino acid at its isoelectric point. *[1]*

. . . . . .
. . . . . .

(This question continues on the following page)

(Question B2 continued)

(b) Explain, using equations, how the amino acid glycine (Gly) can act as a buffer. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

B3. Copper ions are used in electron transport. One reaction that occurs is the oxidation of glucose, $C_6H_{12}O_6$, to form carbon dioxide, CO_2. State the half-equations for the oxidation of glucose and the associated reaction involving copper ions. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

B4. (a) DNA and RNA both contain a pentose sugar.

(i) State the names of the sugars in **each** nucleic acid and outline how their chemical structures differ. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(ii) State **one** other structural difference between DNA and RNA. *[1]*

. . . . . .

(b) (i) Outline the steps involved in DNA profiling. *[5]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question B4 continued)

(ii) State **one** use of DNA profiling. *[1]*

. . . . . .

. . . . . .

Option C — Chemistry in industry and technology

C1. Aluminium and its alloys are widely used in industry.

(a) Aluminium metal is obtained by the electrolysis of alumina dissolved in molten cryolite.

(i) Explain the function of the molten cryolite. *[1]*

. . . . . .
. . . . . .

(ii) State the half-equation for the reaction that takes place at the positive electrode (anode). *[1]*

. . . . . .

(b) Outline **two** different ways that carbon dioxide may be produced during the production of aluminium. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

C2. Catalysts may be homogeneous or heterogeneous.

(a) (i) Explain how a heterogeneous catalyst may increase the rate of the reaction between carbon monoxide, CO(g), and nitrogen monoxide, NO(g). *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(ii) Outline **one** disadvantage of using a heterogeneous catalyst rather than a homogeneous catalyst. *[1]*

. . . . . .
. . . . . .

(b) Discuss **two** factors which need to be considered when selecting a catalyst for a particular chemical process. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question C2 continued)

(c) (i) State the type of reaction for which a Ziegler-Natta catalyst is used. *[1]*

. . . . . .

(ii) Describe the composition of a Ziegler-Natta catalyst. *[2]*

. . . . . .

. . . . . .

. . . . . .

C3. Liquid-crystal displays are used in digital watches, calculators and laptops.

(a) Describe the liquid-crystal state, in terms of molecular arrangement, and explain what happens as temperature increases. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

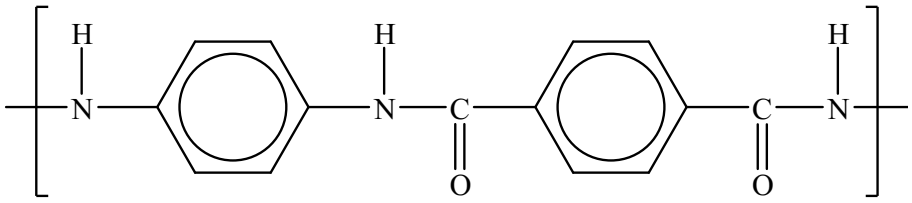
(b) Discuss **three** properties a substance should have if it is to be used in liquid-crystal displays. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question C3 continued)

(c) Kevlar is a condensation polymer that is often used in liquid-crystal displays. A section of the polymer is shown below.



(i) Describe the liquid-crystal properties of Kevlar. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(ii) Explain the strength of Kevlar in terms of its structure and bonding. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(iii) Explain why a bullet-proof vest made of Kevlar should be stored away from acids. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

Option D — Medicines and drugs

D1. Morphine is a strong analgesic which is administered parenterally.

(a) Explain why morphine is normally injected intravenously. *[1]*

. . . . . .

(b) Diamorphine (heroin) is a more effective painkiller than morphine. The structures of morphine and diamorphine are shown in Table 20 of the Data Booklet. Explain at the molecular level why diamorphine is absorbed into fatty tissue more rapidly than morphine. *[2]*

. . . . . .

. . . . . .

. . . . . .

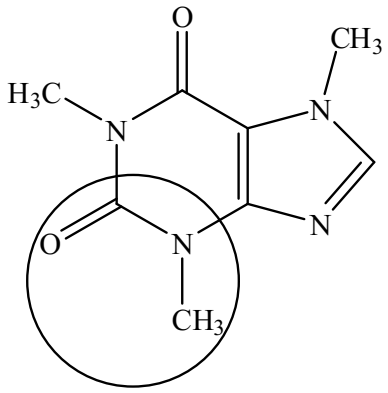
. . . . . .

D2. Caffeine and nicotine are two common stimulants.

(a) Describe **two** effects of large amounts of caffeine on the human body. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) (i) State the name of the functional group circled on the structure of caffeine. *[1]*



. . . . . .

(ii) Deduce which functional group is common to both nicotine and caffeine. *[1]*

. . . . . .

D3. During drug development, trials are conducted to determine the therapeutic window.

(a) Explain the meaning of the term *therapeutic window* and discuss its importance in drug administration. *[4]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) Explain the use of placebos in clinical trials on humans. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(c) Identify **one** other effect of a drug which must be determined during clinical trials. *[1]*

. . . . . .

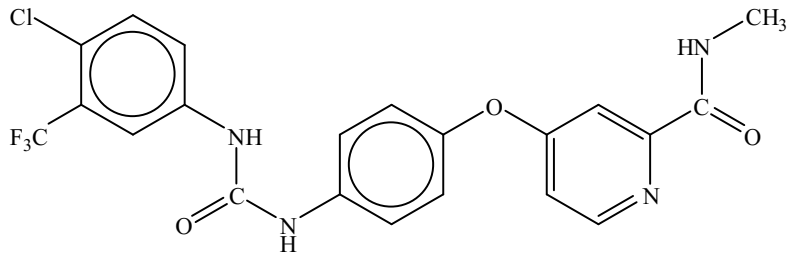
(This question continues on the following page)

(Question D3 continued)

(d) In the 1950s, thalidomide was given to pregnant women to alleviate morning sickness. Many of the children born to these women had deformed limbs. State the structural feature of thalidomide responsible for these different effects and explain the effect that this case has had on the development of drugs. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(e) Sorafenib, a drug used to treat kidney and liver cancer, was produced using combinatorial techniques. The structure of sorafenib is shown below.



(i) Describe how combinatorial chemistry may have been used to synthesize sorafenib. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(ii) State **one** advantage of solid-phase chemistry during combinatorial synthesis. *[1]*

. . . . . .

D4. Several mind-altering drugs exhibit similarities in their structures. Some of these are shown in Table 20 of the Data Booklet.

(a) State **one** structural similarity and **one** difference between lysergic acid diethylamide (LSD) and psilocybin. *[2]*

. . . . . .

. . . . . .

. . . . . .

(b) Describe **two** short-term mind altering effects of tetrahydrocannabinol (THC). *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Option E — Environmental chemistry

E1. Carbon dioxide, methane and chlorofluorocarbons (CFCs) are well-known greenhouse gases. Nitrogen trifluoride, NF_3, is thousands of times more effective at warming the atmosphere than an equal mass of carbon dioxide. NF_3 can be used in the manufacture of computer chips and thin-film solar photovoltaic cells.

(a) Identify **two** greenhouse gases not mentioned above. One of the gases that you identify should contain a nitrogen atom. For each gas, state its source. *[4]*

Greenhouse gas 1:

. . . . . .

Source:

. . . . . .

Greenhouse gas 2:

. . . . . .

Source:

. . . . . .

(b) The methane produced by sheep and cows can contribute to global warming. In Australia, it is considered that sheep and cows produce approximately 14 % of the country's total greenhouse emissions. Explain how this methane is formed. *[1]*

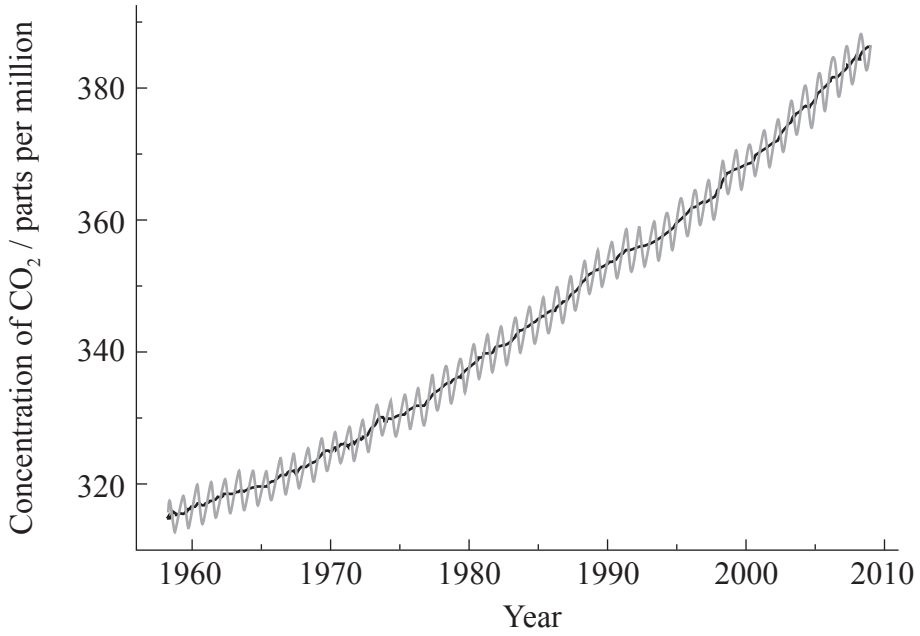
. . . . . .

. . . . . .

(This question continues on the following page)

(Question E1 continued)

(c) The following graph shows the annual increase in the concentration of atmospheric carbon dioxide recorded at Mauna Loa, Hawaii.



[Source: http://scrippsco2.ucsd.edu/graphics_gallery/mauna_loa_record/mauna_loa_record.html]

Explain why the graph is not smooth but involves annual fluctuations (shown in grey). *[1]*

. . . . . .
. . . . . .
. . . . . .

(d) State **one** effect of global warming. *[1]*

. . . . . .
. . . . . .

E2. Fresh supplies of water are of major importance to society today.

(a) Both mercury and polychlorinated biphenyls (PCBs) can potentially cause serious health effects when present in water. State **one** source for each of these two pollutants. *[2]*

Mercury:

. . . . . .

PCBs:

. . . . . .

(b) Fresh water can be obtained from sea water by using multi-stage distillation and reverse osmosis. Evaluate these **two** processes. Your answer should include a description of **each** process. *[5]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

E3. (a) Industrial effluent is found to be highly contaminated with silver and lead ions. A sample of water contains 8.0×10^{-3} mol dm^{-3} Ag^+ and 1.9×10^{-2} mol dm^{-3} Pb^{2+}. On the addition of chloride ions both AgCl ($K_{sp} = 1.8\times10^{-10}$) and $PbCl_2$ ($K_{sp} = 1.7\times10^{-5}$) precipitate from the solution. Determine the concentration of Cl^- needed to initiate the precipitation of each salt and deduce which salt precipitates first. *[5]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) (i) State what is meant by the term *cation-exchange capacity* (CEC). *[1]*

. . . . . .
. . . . . .

(ii) Describe **two** chemical functions of soil organic matter (SOM). *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question E3 continued)

(iii) Discuss how changes in soil pH affects the availability of nitrogen and phosphorus for plants. *[3]*

Nitrogen:

. . . . . .

. . . . . .

. . . . . .

Phosphorus:

. . . . . .

. . . . . .

. . . . . .

Option F — Food chemistry

F1. (a) Rancidity is the perception of flavours in lipids that our senses perceive as off because of a disagreeable smell, taste, texture or appearance. The processes that create the off-flavours may be hydrolytic rancidity or oxidative rancidity in lipids.

(i) Predict the products of hydrolytic rancidity of fats. *[2]*

. . . . . .

. . . . . .

(ii) The hydrolysis of milk products is used in the making of cheese. State **two** conditions which increase the rate of hydrolysis of fats in milk. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(iii) Potato chips (crisps) are cooked in oils made from unsaturated fatty acids. Explain in terms of chemical processes why potato chips are purchased in sealed, opaque, nitrogen-filled foil packs and taste best when freshly opened. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question F1 continued)

(b) Initiation, propagation and termination steps occur in the free-radical chain mechanism during oxidative rancidity. For **each** step, state **one** related equation. *[3]*

Initiation:

. . . . . .

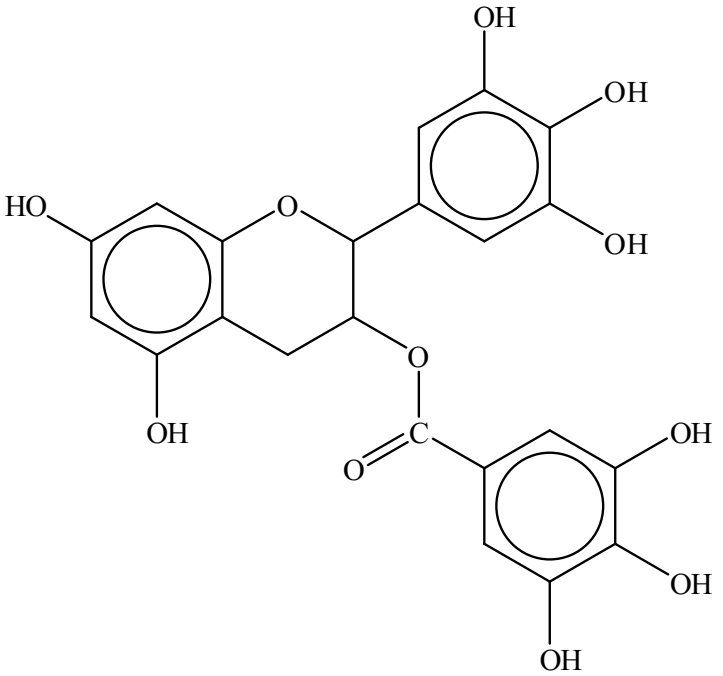
Propagation:

. . . . . .

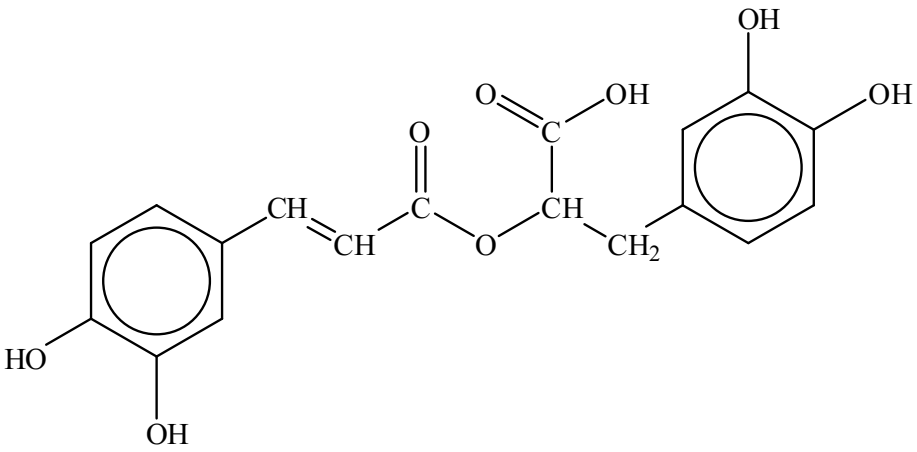
Termination:

. . . . . .

F2. (a) Antioxidants are substances that slow the rate of oxidation of foods and may also be consumed to provide health benefits. Two traditional foods with antioxidant properties are green tea and oregano. Green tea contains epigallocatechin-3-gallate (EGCG) and oregano contains rosmarinic acid. The structures of these two compounds are shown below.



Epigallocatechin-3-gallate (EGCG)



Rosmarinic acid

(i) Explain why both EGCG and rosmarinic acid have antioxidant properties. *[1]*

. . . . . .

. . . . . .

(This question continues on the following page)

(Question F2 continued)

(ii) List **two** health benefits of consuming foods such as green tea and oregano. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) Anthocyanins are naturally occurring pigments responsible for the colour of blueberries and cranberries. The structures of two forms of anthocyanins are shown in Table 22 of the Data Booklet.

(i) Using the abbreviations QB for quinoidal base and FC^+ for flavylium cation, state an equation to describe how pH affects the colour of anthocyanins. *[1]*

. . . . . .

(ii) Suggest why blueberries should not be stored in aluminium cans. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

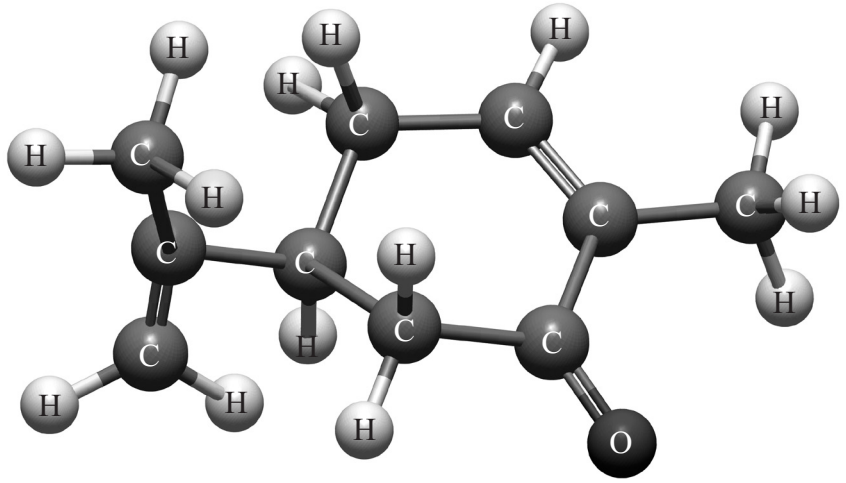
(Question F2 continued)

(c) Compare the structures of the natural pigments, chlorophyll and heme B using Table 22 of the Data Booklet. *[4]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

F3. Carvone is a member of a family of compounds called terpenoids. Carvone occurs in two enantiomeric forms. (*S*)-(+)-carvone is the principal component of caraway seed oil and (*R*)-(–)-carvone is the principal component of spearmint oil.

(a) Identify the chiral centre in carvone, with an asterisk, *. *[1]*



(b) Explain the meaning of the *R* and *S* notation and how this differs from the *d* and *l* notation. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) The structure represented is (*S*)-(+)-carvone. Explain how this has been deduced. *[2]*

. . . . . .

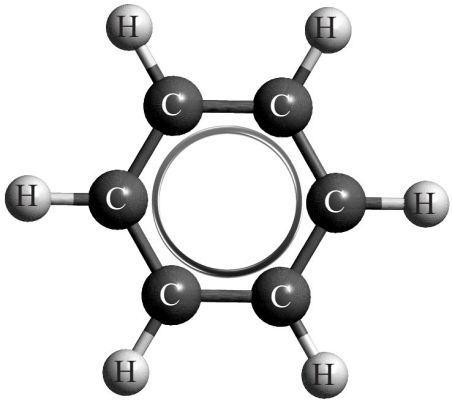
. . . . . .

. . . . . .

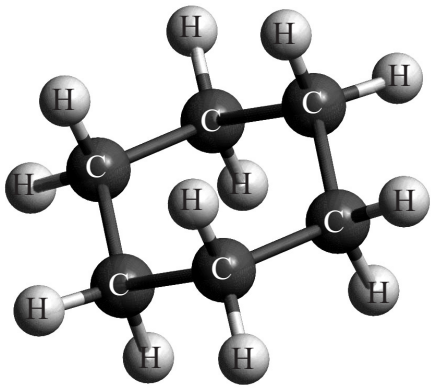
. . . . . .

Option G — Further organic chemistry

G1. Benzene, C_6H_6, is a planar compound which differs from the non-planar structure of cyclohexane, C_6H_{12}. The structures of benzene and the most stable form of cyclohexane are represented below.



Benzene



Cyclohexane

(a) With reference to the compounds benzene, cyclohexane and 1,3-cyclohexadiene, state which compound would contain the shortest carbon-carbon bond length. *[1]*

. . . . . .

(b) Explain why it is more common for benzene to undergo substitution reactions than addition reactions. *[1]*

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question G1 continued)

(c) Suggest why chloromethylbenzene, $C_6H_5CH_2Cl$, reacts with warm aqueous sodium hydroxide, NaOH, easily whereas for chlorobenzene, C_6H_5Cl, stronger conditions such as high temperature (*e.g.* 350 °C) are needed. *[2]*

. . . . . .

. . . . . .

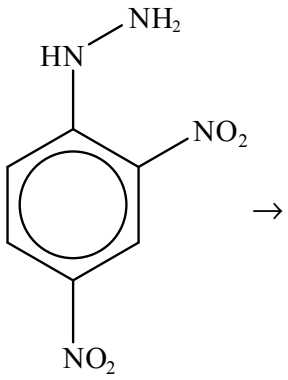
. . . . . .

. . . . . .

G2. (a) Draw the structural formulas of the **major** organic products formed in the following reactions.

(i) $H_3CCH{=}CH_2 + ICl \rightarrow$ *[1]*

(ii) $H_3CCHO + HCN \rightarrow$ *[1]*

(iii) $H_3CCHO +$  $\rightarrow$ *[1]*

(iv) $CH_3MgI \xrightarrow[2.\ H_2O]{1.\ H_3CCHO}$ *[1]*

(This question continues on the following page)

(Question G2 continued)

(b) Draw the structural formula of the other product of the reaction in part (a) (i). *[1]*

(c) Identify each of the types of reaction in (a) as elimination, nucleophilic addition, electrophilic addition, acid-base, addition-elimination or Grignard. *[4]*

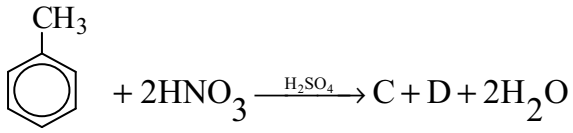
Reaction	Type
(a) (i)	
(a) (ii)	
(a) (iii)	
(a) (iv)	

G3. (a) Identify **all** the **major** products, **A**–**D**, in the following reactions.

(i) $CH_3COCl + CH_3CH_2NH_2 \rightarrow \mathbf{A} + \mathbf{B}$ *[1]*

A:

B:

(ii) 

[1]

C:

D:

(b) **C** and **D** are isomers. Explain the mechanism of the reaction in (a) (ii), forming one of these two isomers, using curly arrows to represent the movement of electron pairs. *[3]*

G4. Benzene reacts with ethanoyl chloride, CH_3COCl, in the presence of an aluminium chloride catalyst, $AlCl_3$, in an acylation reaction. Explain the mechanism of the reaction, using curly arrows to represent the movement of electron pairs. Include the formation of the electrophile. *[4]*

G5. Deduce a two-step reaction pathway which can be used to convert butan-1-ol, $CH_3(CH_2)_3OH$, into 1,2-dibromobutane, $CH_3CH_2CHBrCH_2Br$. State the reagents used in each step and identify the product formed in step 1. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

Please **do not** write on this page.

Answers written on this page
will not be marked.

Please **do not** write on this page.

Answers written on this page
will not be marked.